HEATING, VENTILATING AND AIR CONDITIONING (HVAC) CONTROL SYSTEMS Table of Contents

CHAPTER 1. (GEN	ERAL	Page
Paragraph	1.	Purpose	1-1
	2.	Scope	1-1
	3.	References	1-1
	4.	Policy	1-1
	5.	Control system designer guidance	1-1
	6.	Design concept	1-2
	7.	DDC versus SLDC	1-2
	8.	Control system standards	1-5
	9.	Project implementation	1-7
	10.	Design package requirements for HVAC control systems	1-8
	11.	EMCS interface with standard local control panels	1-10
	12.	Fan starter control circuit override by external control systems	1-13
	13.	Coordination with HVAC system balancing	1-13
	14.	Symbols	1-13
	15.	Explanation of terms	1-13
CHAPTER 2. H		C CONTROL SYSTEM EQUIPMENT, EQUIPMENT USES AND HVAC CON OOPS	ITROL
Paragraph	1.	General	2-1
	2.	Control system operating modes and process variables	2-1
	3.	Control system equipment	2-2
	4.	Control loops	2-14

	5.	Open control loops
	6.	Closed control loops
	7.	Application of open-loop control and closed-loop control to HVAC systems. 2-15
	8.	Typical control modes
	9.	Standard HVAC system control loops
	10.	Sizing and selection of control system devices
	11.	Sizing of the air compressor motor
	12.	Determination of control valve flow coefficient (K $_{\!\scriptscriptstyle V}$ / C $_{\!\scriptscriptstyle V}$) 2-22
	13.	Calculation of liquid control valve flow coefficient (K $_{\!_{V}}$ / C $_{\!_{V}}$) $$ 2-22
	14.	Calculation of steam control valve flow coefficient (K $_{\rm v}$ / C $_{\rm v}$) 2-25
	15.	Determining valve actuator close-off pressure ratings 2-29
	16.	Surge protection provisions for transmitter and control wiring 2-30
CHAPTER 3.	STA	NDARD CONTROL LOOPS
Paragraph	1.	General
	2.	Cooling coil temperature control loop
	3.	Outside air preheat coil temperature control loop
	4.	Heating coil temperature control loop
	5.	Mixed air temperature and economizer control loops
	6.	Minimum outside air control loop for VAV HVAC systems
	7.	Supply duct static pressure control loop
	8.	Return fan volume control loop
	9.	Humidifier control loop
	10.	The typical schematic
	11.	The typical ladder diagram

	12.	The typical equipment schedule	
	13.	The typical data terminal strip (DTS) layout	
CHAPTER 4.	STA	NDARD HVAC CONTROL SYSTEMS	
Paragraph	1.	General	
	2.	Identification of control system devices	
	3.	Project specific drawings	
	4.	Space temperature controlled perimeter radiation control system 4-2	
	5.	Unit heater temperature control system4-2	
	6.	Gas-fired infrared heater control system	
	7.	Small packaged unitary system control system	
	8.	Dual-temperature fan coil unit control system	
	9.	Control systems that require control panels	
	10.	Standard single-loop controller HVAC control panel	
	11.	Central plant steam hydronic heating control system 4-6	
	12.	Single building hydronic heating with hot water boiler control system 4-8	
	13.	Central plant high-temperature hot water hydronic heating control system . 4-10	
	14.	Central plant steam dual-temperature hydronic control system 4-13	
	15.	Central plant high-temperature hot water dual-temperature hydronic control system	
	16.	Single building dual-temperature hydronic control system 4-17	
	17.	Heating and ventilating control system	
	18.	Multizone HVAC control system with return fan	
	19.	Dual-duct HVAC control system with return fan	
	20.	Bypass multizone HVAC control system with return fan	
	21	Variable air volume (VAV) HVAC control system without return fan 4-37	

22.	Variable air volume (VAV) HVAC control system with return fan 4-42
23.	Single zone HVAC control system
24.	Dual-temperature coil single zone HVAC control system
25.	Single zone HVAC control system with humidity control 4-56
26.	Single zone HVAC control system with direct-expansion (DX) cooling coil . 4-60
CHAPTER 5. CON	NTROL SYSTEM DESIGN VARIATIONS
Paragraph 1.	General
2.	Control system variations for 100-percent outside air (continuous operation)
3.	Control system variations for exhaust fans5-2
4.	Control system variations for smoke dampers5-2
5.	Control system variations for variable speed drives5-3
6.	Control system variations for steam preheat coil with face and bypass damper
7.	Control system variation for hot water or glycol preheat coil 5-4
8.	Control system variation for combining hydronic system and air system controls in the same control panel
9.	Unoccupied mode space temperature setback control for terminal units 5-4
10.	Control system variations for 2-way shutoff valves for fan coil units 5-4
11.	Control system variation for building purge / flush cycle 5-5
12.	Control system variations for EMCS initiated building purge and recirculation modes
13.	Control system variations for smoke control and freeze protection 5-6
14.	Control system variations for non-economizer HVAC systems 5-6
15.	Control system variations for dual steam valves 5-7
16.	Control system variations for hydronic systems with boilers requiring

CHAPTER 6.	RETROFIT OF EXISTING HVAC CONTROL SYSTEMS	
Paragraph	1. Introduction	
	2. Valve sizing and its effect on hydronic systems	
	3. Damper sizing and its effect on air handling systems 6-1	
	4. Replacement of 3-way and 2-way valves	
	5. Retrofit projects where only final elements may be left in place 6-1	
	6. Retrofits involving economizer control loops 6-1	
	7. Retrofit projects involving HVAC systems not covered in this manual 6-2	
	8. General considerations for retrofit projects	
GLOSSARY	Glossary 1	
	LIST OF FIGURES	
Figure	Title	
2-1. 2-2. 2-3. 2-4. 2-5. 2-6. 2-7. 2-8. 2-9.	Two butterfly valves on a common pipe tee. Conversion of an electronic signal to a pneumatic signal. Simultaneous heating and cooling with pneumatic actuators without positive positioner Control system with positive positioners to avoid simultaneous heating and cooling. Modulating control circuits impedance limitation. Manual reset feature. Control loop. Open control loop. Closed control loop. Two loops controlling one device (humidity control with high limit).	s
2-10. 2-11. 2-12. 2-13. 2-14. 2-15.	Two-position control. Simple control loop applied to outside air heating. Proportional control mode. Proportional plus integral control mode. Comparison of P mode, PI mode and PID mode for a step change in setpoint and the contributions of each mode to controller output signal.	
2-16. 2-17. 2-18. 3-1. 3-2. 3-3. 3-4. 3-5.	Typical normally-open pneumatic valve. Close-off pressure for two-way valves. Close-off pressure for three-way valves. Cooling coil temperature control loop. Outside air preheat coil temperature control loop. Heating coil temperature control loop (scheduled from outside air temperature). Outside air temperature controller input / output schedule. Heating coil temperature control loop with heating coil controlled at a constant temperature.	

3-6.	Mixed air temperature and economizer control loops.
3-7.	Design condition for economizer mode operation.
3-8.	Selecting the economizer switchover point.
3-9.	Effect on energy conservation of selection of the economizer switchover point.
3-10.	Minimum outside air and mixed air temperature / economizer control loops for VAV
	systems.
3-11.	Supply duct static pressure control loop.
3-12.	Return fan volume control loop.
3-13.	Humidifier control loop.
3-14.	Typical single-loop controller schematic.
3-15.	Typical DDC schematic.
3-16.	Typical ladder diagram.
3-17.	Typical equipment schedule.
3-18.	Typical DDC data terminal strip layout.
4-1.	Space temperature controlled perimeter radiation control system.
4-2.	Unit heater temperature control system.
4-3.	Gas-fired infrared heater temperature control system.
4-4.	Small packaged unitary system control system.
4-5.	Dual-temperature fan coil unit temperature control system.
4-6a.	Standard wall-mounted HVAC control panel arrangement.
4-6b.	Section "A-A" through standard HVAC control panel.
4-6c.	Standard HVAC control panel interior door.
4-6d.	Standard HVAC control panel back panel layout.
4-6e.	Standard HVAC control panel terminal block assignments.
4-6f.	Controller wiring.
4-6g.	Supply fan and return fan starter wiring.
4-6h.	Exhaust fan and pump starter wiring.
4-6i.	HVAC control panel power wiring.
4-7a.	Control system schematic for central plant steam hydronic system.
4-7b.	Control system ladder diagram for central plant steam hydronic system.
4-7c.	Control system equipment for central plant steam hydronic system.
4-7d.	Control panel interior door layout for central plant steam hydronic system.
4-7e.	Control panel back panel layout for central plant steam hydronic system.
4-7f.	Control panel terminal block layout for central plant steam hydronic system.
4-7g.	DDC control system schematic for central plant steam hydronic system.
4-7h.	DDC control system ladder diagram for central plant steam hydronic system.
4-7i.	DDC control system equipment for central plant steam hydronic system.
4-7j.	DDC control system I/O table and data terminal strip layout for central plant steam
· / J.	hydronic system.
4-8a.	Control system schematic for single building hydronic heating system with hot water
	boiler.
4-8b.	Control system ladder diagram for single building hydronic heating system with hot water
. 00.	boiler.
4-8c.	Control system equipment for single building hydronic heating system with hot water
	boiler.
4-8d.	Control panel interior door layout for single building hydronic heating system with hot
	water boiler.
4-8e.	Control panel back panel layout for single building hydronic heating system with hot
	water boiler.

4-8f.	Control panel terminal block layout for single building hydronic heating system with hot water boiler.
4-8g.	DDC control system schematic for single building hydronic heating system with hot water boiler.
4-8h.	DDC control system ladder diagram for single building hydronic heating system with hot water boiler.
4-8i.	DDC control system equipment for single building hydronic heating system with hot water boiler.
4-8j.	DDC control system I/O table and data terminal strip layout for single building hydronic heating system with hot water boiler.
4-9a.	Control system schematic for central plant high-temperature hot water hydronic heating system.
4-9b.	Control system ladder diagram for central plant high-temperature hot water hydronic heating system.
4-9c.	Control system equipment for central plant high-temperature hot water hydronic heating system.
4-9d.	Control panel interior door layout for central plant high-temperature hot water hydronic heating system.
4-9e.	Control panel back panel layout for central plant high-temperature hot water hydronic heating system.
4-9f.	Control panel terminal block layout for central plant high-temperature hot water hydronic heating system.
4-9g.	DDC control system schematic for central plant high-temperature hot water hydronic heating system.
4-9h.	DDC control system ladder diagram for central plant high-temperature hot water hydronic heating system.
4-9i.	DDC control system equipment for central plant high-temperature hot water hydronic heating system.
4-9j.	DDC control system I/O table and data terminal strip layout for central plant high-temperature hot water hydronic heating system.
4-10a.	Control system schematic for central plant steam dual-temperature hydronic system.
4-10a. 4-10b.	Control system schematic for central plant steam dual-temperature hydronic system. Control system ladder diagram for central plant steam dual-temperature hydronic system.
4-10c.	Control system equipment for central plant steam dual-temperature hydronic system.
4-10d. 4-10d.	Control system equipment for central plant steam dual-temperature hydronic system. Control panel interior door layout for central plant steam dual-temperature hydronic system.
4-10e.	Control panel back panel layout for central plant steam dual-temperature hydronic system.
4-10f.	Control panel terminal block layout for central plant steam dual-temperature hydronic system.
4-10g.	DDC control system schematic for central plant steam dual-temperature hydronic system.
4-10h.	DDC control system ladder diagram for central plant steam dual-temperature hydronic system.
4-10i.	DDC control system equipment for central plant steam dual-temperature hydronic system.
4-10j.	DDC control system I/O table and data terminal strip layout for central plant steam dual-temperature hydronic system.
4-11a.	Control system schematic for central plant high-temperature hot water dual-temperature hydronic system.

4-11b.	Control system ladder diagram for central plant high-temperature hot water dual-temperature hydronic system.
4-11c.	Control system equipment for central plant high-temperature hot water dual-temperature
1 114	hydronic system.
4-11d.	Control panel interior door layout for central plant high-temperature hot water dual-temperature hydronic system.
4-11e.	Control panel back panel layout for central plant high-temperature hot water dual-temperature hydronic system.
4-11f.	Control panel terminal block layout for central plant high-temperature hot water dual-temperature hydronic system.
4-11g.	DDC control system schematic for central plant high-temperature hot water dual-temperature hydronic system.
4-11h.	DDC control system ladder diagram for central plant high-temperature hot water dual-temperature hydronic system.
4-11i.	DDC control system equipment for central plant high-temperature hot water dual-temperature hydronic system.
4-11j.	DDC control system I/O table and data terminal strip layout for central plant high-temperature hot water dual-temperature hydronic system.
4-12a.	Control system schematic for single building dual-temperature hydronic system.
4-12b.	Control system ladder diagram for single building dual-temperature hydronic system.
4-12c.	Control system equipment for single building dual-temperature hydronic system.
4-12d.	Control panel interior door layout for single building dual-temperature hydronic system.
4-12e.	Control panel back panel layout for single building dual-temperature hydronic system.
4-12f.	Control panel terminal block layout for single building dual-temperature hydronic system.
4-12g.	DDC control system schematic for single building dual-temperature hydronic system.
4-12h.	DDC control system ladder diagram for single building dual-temperature hydronic system.
4-12i.	DDC control system equipment for single building dual-temperature hydronic system.
4-12j.	DDC control system I/O table and data terminal strip layout for single building dual-temperature hydronic system.
4-13a.	Control system schematic for heating and ventilating system.
4-13b.	Control system ladder diagram for heating and ventilating system.
4-13c.	Control system equipment for heating and ventilating system.
4-13d.	Control panel interior door layout for heating and ventilating system.
4-13e.	Control panel back panel layout for heating and ventilating system.
4-13f.	Control panel terminal block layout for heating and ventilating system.
4-13g.	DDC control system schematic for heating and ventilating system.
4-13h.	DDC control system ladder diagram for heating and ventilating system.
4-13i.	DDC control system equipment for heating and ventilating system.
4-13j.	DDC control system I/O table and data terminal strip layout for heating and ventilating system.
4-14a.	Control system schematic for multizone HVAC system.
4-14b.	Control system ladder diagram for multizone HVAC system.
4-14c.	Control system equipment for multizone HVAC system.
4-14d.	Control panel interior door layout for multizone HVAC system.
4-14e.	Control panel back panel layout for multizone HVAC system.
4-14f.	Control panel terminal block layout for multizone HVAC system.
4-14g.	DDC control system schematic for multizone HVAC system.
4-14h.	DDC control system ladder diagram for multizone HVAC system.
4-14i.	DDC control system equipment for multizone HVAC system.

4-14j.	DDC control system I/O table and data terminal strip layout for multizone HVAC system.
4-15a.	Control system schematic for dual-duct HVAC system.
4-15b.	Control system ladder diagram for dual-duct HVAC system.
4-15c.	Control system equipment for dual-duct HVAC system.
4-15d.	Control panel interior door layout for dual-duct HVAC system.
4-15e.	Control panel back panel layout for dual-duct HVAC system.
4-15f.	Control panel terminal block layout for dual-duct HVAC system.
4-15g.	DDC control system schematic for dual-duct HVAC system.
4-15h.	DDC control system ladder diagram for dual-duct HVAC system.
4-15i.	DDC control system equipment for dual-duct HVAC system.
4-15j.	DDC control system I/O table and data terminal strip layout for dual-duct HVAC system.
4-16a.	Control system schematic for bypass multizone HVAC system.
4-16b.	Control system ladder diagram for bypass multizone HVAC system.
4-16c.	Control system equipment for bypass multizone HVAC system.
4-16d.	Control panel interior door layout for bypass multizone HVAC system.
4-16e.	Control panel back panel layout for bypass multizone HVAC system.
4-16f.	Control panel terminal block layout for bypass multizone HVAC system.
4-16g.	DDC control system schematic for bypass multizone HVAC system.
4-16h.	DDC control system ladder diagram for bypass multizone HVAC system.
4-16i.	DDC control system equipment for bypass multizone HVAC system.
4-16j.	DDC control system I/O table and data terminal strip layout for bypass multizone HVAC
4-10j.	system.
4 170	•
4-17a.	Control system schematic for VAV HVAC system without return fan.
4-17b.	Control system ladder diagram for VAV HVAC system without return fan.
4-17c.	Control system equipment for VAV HVAC system without return fan.
4-17d.	Control panel interior door layout for VAV HVAC system without return fan.
4-17e.	Control panel back panel layout for VAV HVAC system without return fan.
4-17f.	Control panel terminal block layout for VAV HVAC system without return fan.
4-17g.	DDC control system schematic for VAV HVAC system without return fan.
4-17h.	DDC control system ladder diagram for VAV HVAC system without return fan.
4-17i.	DDC control system equipment for VAV HVAC system without return fan.
4-17j.	DDC control system I/O table and data terminal strip layout for VAV HVAC system
	without return fan.
4-18a.	Control system schematic for VAV HVAC system with return fan.
4-18b.	Control system ladder diagram for VAV HVAC system with return fan.
4-18c.	Control system equipment for VAV HVAC system with return fan.
4-18d.	Control panel interior door layout for VAV HVAC system with return fan.
4-18e.	Control panel back panel layout for VAV HVAC system with return fan.
4-18f.	Control panel terminal block layout for VAV HVAC system with return fan.
4-18g.	DDC control system schematic for VAV HVAC system with return fan.
4-18h.	DDC control system ladder diagram for VAV HVAC system with return fan.
4-18i.	DDC control system equipment for VAV HVAC system with return fan.
4-18j.	DDC control system I/O table and data terminal strip layout for VAV HVAC system with
-	return fan.
4-19a.	Control system schematic for single zone HVAC system.
4-19b.	Control system ladder diagram for single zone HVAC system.
4-19c.	Control system equipment for single zone HVAC system.
4-19d.	Control panel interior door layout for single zone HVAC system.
4-19e.	Control panel back panel layout for single zone HVAC system.
4-19f.	Control panel terminal block layout for single zone HVAC system.
	, 5

4-19g.	DDC control system schematic for single zone HVAC system.
4-19h.	DDC control system ladder diagram for single zone HVAC system.
4-19i.	DDC control system equipment for single zone HVAC system.
4-19j.	DDC control system I/O table and data terminal strip layout for single zone HVAC
•	system.
4-20a.	Control system schematic for single zone HVAC system with dual-temperature coil.
4-20b.	Control system ladder diagram for single zone HVAC system with dual-temperature coil.
4-20c.	Control system equipment for single zone HVAC system with dual-temperature coil.
4-20d.	Control panel interior door layout for single zone HVAC system with dual-temperature
	coil.
4-20e.	Control panel back panel layout for single zone HVAC system with dual-temperature coi
4-20f.	Control panel terminal block layout for single zone HVAC system with dual-temperature
	coil.
4-20g.	DDC control system schematic for single zone HVAC system with dual-temperature coil.
4-20h.	DDC control system ladder diagram for single zone HVAC system with dual-temperature
. 20	coil.
4-20i.	DDC control system equipment for single zone HVAC system with dual-temperature coil
4-20j.	DDC control system I/O table and data terminal strip layout for single zone HVAC
. 20j.	system with dual-temperature coil.
4-21a.	Control system schematic for single zone HVAC system with humidity control.
4-21b.	Control system ladder diagram for single zone HVAC system with humidity control.
4-21c.	Control system equipment for single zone HVAC system with humidity control.
4-21d.	Control panel interior door layout for single zone HVAC system with humidity control.
4-21e.	Control panel back panel layout for single zone HVAC system with humidity control.
4-21f.	Control panel terminal block layout for single zone HVAC system with humidity control.
4-21g.	DDC control system schematic for single zone HVAC system with humidity control.
4-21h.	DDC control system ladder diagram for single zone HVAC system with humidity control.
4-21i.	DDC control system equipment for single zone HVAC system with humidity control.
4-21j.	DDC control system I/O table and data terminal strip layout for single zone HVAC
,.	system with humidity control.
4-22a.	Control system schematic for single zone HVAC system with DX coil.
4-22b.	Control system ladder diagram for single zone HVAC system with DX coil.
4-22c.	Control system equipment for single zone HVAC system with DX coil.
4-22d.	Control panel interior door layout for single zone HVAC system with DX coil.
4-22e.	Control panel back panel layout for single zone HVAC system with DX coil.
4-22f.	Control panel terminal block layout for single zone HVAC system with DX coil.
4-22g.	DDC control system schematic for single zone HVAC system with DX coil.
4-22h.	DDC control system ladder diagram for single zone HVAC system with DX coil.
4-22i.	DDC control system equipment for single zone HVAC system with DX coil.
4-22j.	DDC control system I/O table and data terminal strip layout for single zone HVAC
,.	system with DX coil.
5-1.	Schematic variations for 100-percent outside air systems.
5-2.	Ladder diagram variations for 100-percent outside air systems.
5-3.	Schematic variations for exhaust fans.
5-4.	Ladder diagram variations for exhaust fans.
5-5.	Schematic variations for smoke dampers.
5-6.	Ladder diagram variations for smoke dampers.
5-7a.	Schematic variations for variable speed drives.
5-7b.	Ladder diagram variations for variable speed drives.
5-7c.	Equipment variations for variable speed drives.
-	and the contract of the contra

5-7d.	Control panel interior door layout variations for variable speed drives.
5-7e.	Control panel back panel layout variations for variable speed drives.
5-7f.	Control panel terminal block layout variations for variable speed drives.
5-7g.	DDC schematic variations for variable speed drives.
5-7h.	DDC ladder diagram variations for variable speed drives.
5-7i.	DDC schedule variations for variable speed drives.
5-7j.	DDC I/O table and data terminal strip layout variations for variable speed drives.
5-8.	Control system variations for steam preheat coil with face and bypass dampers.
5-9.	Control system variations for unoccupied mode setback (perimeter radiation).
5-10.	Control system variations for unoccupied mode setback (unit heater).
5-11.	Control system variations for 2-way shutoff valve on fan coil units.
5-12a.	Control system schematic for multizone HVAC system with building flush mode of
	operation
5-12b.	Control system ladder diagram for multizone HVAC system with building flush mode of
	operation.
5-12c.	Control system equipment for multizone HVAC system with building flush mode of
0 .20.	operation.
5-12d.	Control panel interior door layout for multizone HVAC system with building flush mode of
0 .20.	operation.
5-12e.	Control panel back panel layout for multizone HVAC system with building flush mode of
0 120.	operation.
5-12f.	Control panel terminal block layout for multizone HVAC system with building flush mode
0 121.	of operation.
5-13.	Control system variations for EMCS building purge and recirculation modes for
J-10.	pneumatic actuators.
5-14.	Control system variations for EMCS building purge and recirculation modes for electric
J-14.	or electronic actuators.
5-15a.	Control system schematic for single-zone HVAC system without economizer control
J-13a.	mode.
5-15b.	Control system ladder diagram for single-zone HVAC system without economizer control
J-10D.	mode.
5-15c.	Control system equipment for single-zone HVAC system without economizer control
J-130.	mode.
5-15d.	Control panel interior door layout for single-zone HVAC system without economizer
5-15u.	control mode.
5-15e.	Control panel back panel layout for single-zone HVAC system without economizer
5-15 c .	control mode.
5 15f	
5-15f.	Control panel terminal block layout for single-zone HVAC system without economizer control mode.
E 15a	DDC control system schematic for single-zone HVAC system without economizer control
5-15g.	,
E 15h	mode.
5-15h.	DDC control system ladder diagram for single-zone HVAC system without economizer
5-15i.	control mode.
5-151.	DDC control system equipment for single-zone HVAC system without economizer control
5 15i	mode. DDC control system I/O table and data terminal atria layout for single zone HV/AC
5-15j.	DDC control system I/O table and data terminal strip layout for single-zone HVAC
E 16	system without economizer control mode.
5-16.	Schematic variations for dual steam valves.
5-17.	Equipment schedule variations for dual steam valves.

5-18a.	Control system schematic for single building hydronic heating system with constant volume hot water boiler loop.
5-18b.	Control system ladder diagram for single building hydronic heating system with constant volume hot water boiler loop.
5-18c.	Control system equipment for single building hydronic heating system with constant volume hot water boiler loop.
5-18d.	Control panel interior door layout for single building hydronic heating system with constant volume hot water boiler loop.
5-18e.	Control panel back panel layout for single building hydronic heating system with constant volume hot water boiler loop.
5-18f.	Control panel terminal block layout for single building hydronic heating system with constant volume hot water boiler loop.
5-18g.	DDC control system schematic for single building hydronic heating system with constant volume hot water boiler loop.
5-18h.	DDC control system ladder diagram for single building hydronic heating system with constant volume hot water boiler loop.
5-18i.	DDC control system equipment for single building hydronic heating system with constant volume hot water boiler loop.
5-18j.	DDC control system I/O table and data terminal strip layout for single building hydronic heating system with constant volume hot water boiler loop.
5-19a.	Control system schematic for single building dual-temperature hydronic system with constant volume boiler loop.
5-19b.	Control system ladder diagram for single building dual-temperature hydronic system with constant volume boiler loop.
5-19c.	Control system equipment for single building dual-temperature hydronic system with constant volume boiler loop.
5-19d.	Control panel interior door layout for single building dual-temperature hydronic system with constant volume boiler loop.
5-19e.	Control panel back panel layout for single building dual-temperature hydronic system with constant volume boiler loop.
5-19f.	Control panel terminal block layout for single building dual-temperature hydronic system with constant volume boiler loop.
5-19g.	DDC control system schematic for single building dual-temperature hydronic system with constant volume boiler loop.
5-19h.	DDC control system ladder diagram for single building dual-temperature hydronic system with constant volume boiler loop.
5-19i.	DDC control system equipment for single building dual-temperature hydronic system with constant volume boiler loop.
5-19j.	DDC control system I/O table and data terminal strip layout for single building dual-temperature hydronic system with constant volume boiler loop.

LIST OF TABLES

Table	Title
1-1.	Commissioning procedure.
2-1.	Controller features.
2-2.	Air consumption of control devices.
2-3	Available control valves with Cy in the range of 16 to 25